Safety concerns associated with the use of electrically powered haulage to remove workers from mines during main fan stoppages

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ABSTRACT: The roles of main mine fans in underground mines are to induce airflow and continuously remove hazardous gases and dust. While most larger mines use multiple fans to accomplish these tasks, many smaller mines employ only a single fan. This paper concentrates on those mines having only one fan to provide ventilation needs. If this fan should cease to function, it is likely that methane concentrations will increase in some areas of the mine. As a safety precaution, Federal Regulations require that personnel must begin evacuating the mine within fifteen minutes after fan stoppage. Powered haulage can be used to transport workers to the mine portal as long as travel is through areas where hazardous levels of methane are not expected. To determine where methane will accumulate along haulageways during a fan stoppage, air samples must be taken at specific areas and analyzed for hazardous gases.

During this study, procedures were developed for measuring methane levels along haulageways that are used to exit a mine following stoppage of the main mine fan. Methane levels were measured in four different mines at selected underground locations during four planned fan stoppages. In these mines the measurements taken only at the specified locations showed that, if workers had used electrically powered haulage to exit the mine following a fan stoppage, the methane accumulated along haulageways during fan stoppages would not have significantly increased the risk of an ignition.

1 BACKGROUND

An entry in an underground coal mine through which equipment, personnel and, in some instances, coal are transported is called a haulageway. This entry is always ventilated by intake or fresh air. If trolley wires are located within the haulageway, the air velocity through that entry is limited to 250 ft/min, unless mine personnel are unable to keep methane levels below one percent. If, during an underground emergency, a mine evacuation is ordered, haulageways become escapeways. Because they are ventilated by fresh air, these entries are usually the most direct paths out of the mine.

Federal regulation 30 CFR 75:313 requires that, if a mine fan stops and ventilation is not restored within 15 minutes, all persons must be withdrawn from the mine. In addition, all underground electrical circuits must be de-energized. However those circuits required to assist miners evacuating the mine may remain energized if they are located in areas or haulageways where methane is not likely to migrate or accumulate. Section 221 (d) of the Bituminous Coal Mining Laws of Pennsylvania requires that in case of accident to a ventilation fan or its machinery, or if the fan stoppage is planned whereby the ventilation of the mine is interrupted, the mine foreman shall order the power to be disconnected from the affected portions and withdraw the men immediately from the face areas. If the fan has been stopped for a period of time in excess of fifteen minutes in a gassy mine, the mine foreman shall order the men withdrawn from the mine.

Following a withdrawal order, two methods of escape are typically available to miners; ride out in an available vehicle or walk out. In most mines, the fastest way for workers to reach the shaft or portal is by using powered haulage. Ideally, the time required to ride out depends only on the distance of the work location from the surface and the speed of the vehicle. Elapsed time is often increased because of traffic in the entry. The time required for workers to evacuate on-foot depends on several factors, including, once again, the distance of the work location from the surface, the height of the coal seam and the general condition of the haulageways. In addition, the physical condition of the miners, including their age, endurance and mobility, affects how quickly they can reach the shaft or portal. It is the overall effect of these factors that determines worker safety during evacuation from the mine.

In most coal mines located beneath the water table, methane liberation is a continuous process. Whenever the mine fan stops, methane concentrations are expected to increase in some areas of the mine. If the concentration of methane exceeds its lower explosive limit (LEL), normally considered to be 5 pct in air, the potential for an ignition and explosion becomes real. Removing workers from the mine as quickly as practical following a fan stoppage reduces the chances of injury or death should an ignition occur.

Haulageways are always intake or fresh air entries. Most mines have little data available to identify specific areas where methane concentrations could be of concern, especially when fan operation is interrupted. If engineers did take samples in a haulageway, those readings would most likely be obtained while the fan was operating. These samples would not necessarily be indicative of high methane concentration areas when the fan was not operating.

Using electrically powered vehicles to remove workers from the mine during a fan stoppage assumes that methane levels along haulageways are not yet high enough to present an ignition risk. Although the highest methane levels along haulageways are normally expected in "high points," areas adjacent to abandoned workings, or areas not swept by ventilating air flow, these values are normally well below the LEL. In fact, 30 CFR 75:327 requires that the methane concentration in trolley haulageways always be less than one percent. However, while there are regulations that specify the procedure, location and instrumentation for monitoring methane at the mining face, no similar regulations or guidelines are available for making methane measurements along haulageways.

The objectives of this work were twofold. First, researchers wanted to provide guidelines for monitoring methane levels along haulageways. This included identifying instrumentation needed for data collection, determining the areas along haulageways where methane is most likely to accumulate, and deciding on locations in each area for positioning the methanometer to insure representative readings. Second, mine personnel and researchers wanted to conduct methane sampling during planned mine fan stoppages. The purpose was to demonstrate the procedures necessary for measuring methane concentrations, and evaluate the potential risk factors associated with using electrically powered haulage to remove workers from the mine during a fan stoppage.

2 TEST PROCEDURES

2.1 *Sampling instrumentation*

Four different methanometers, obtained from three manufacturers, were used during the underground tests to monitor gas along the haulageways. Sensors in three of the methanometers employed catalytic heat-of-combustion detectors while the fourth used an infrared sensor. Each methanometer was 1) approved by MSHA for use underground (intrinsically safe), 2) battery operated, 3) portable enough to be carried to each of the sampling areas, and 4) equipped with a data recording (logging) device.

In three methanometers the data loggers were located internally to the instrument; the fourth logger was connected externally to the methanometer. These loggers recorded methane concentration data for either 30 or 60-second time intervals.

To determine methane concentrations at the mine fan, air samples were taken just outby the fan. These were collected by inserting a 20-ml, 96 pct-air-evacuated glass test tube into a plastic plunger. This assembly was similar to a device used to extract blood for clinical testing. A hypodermic needle was attached to the inside of the plunger. As the tube was moved into the plunger the needle punctured a rubber bladder at one end of the test tube. The pressure difference between atmospheric and the inside of the test tube caused an air sample to enter the tube. Pulling the test tube from the plunger resealed the rubber bladder and prevented the gas sample from escaping or being contaminated. These samples were then returned to the laboratory and analyzed for methane content using gas chromatography (GC). The accuracy of the GC instrument is about 1 ppm or 0.0001 pct.

2.2 *Sampling locations*

Certain guidelines were applied to prioritize potential areas where methane was most likely to accumulate. Guidelines for likely sampling locations included those near high points in the roof that were due to, for example, a fall of roof, an old overcast area, the inclination of a seam, or a fault zone. Preferred sampling locations were also in areas where air velocities were lowest, and areas proximal to mined-out workings that continue to be ventilated, or near sealed old workings or gob areas.

In the four underground studies, methane samples were taken at underground locations and on the surface just outby the main mine fan. Based on their experience and our guidelines, mine officials selected the haulageway sampling locations in all four tests. Most of the haulageway locations were along routes taken by miners traveling between the working sections and the surface. Other selected locations, such as bleeder evaluation points, were near the haulageways. NIOSH researchers determined the remaining underground locations. These were at the working faces and in the returns of active sections. Researchers also obtained gas samples at the main mine fan prior to fan shutdown and again following fan restart.

To obtain the best estimate of the highest methane concentration at a specific location, researchers wanted to optimize methanometer positioning relative to the entry geometry. At each location a methanometer was positioned as close as practical to the rib-roof intersection but not closer than one foot from the rib or roof. Mine officials found locations where ventilation airflow velocities were minimal. Finally, locations were selected that were near to and above trolley wires.

3 METHANE SAMPLING

3.1 *Underground*

Studies to measure methane levels during planned mine fan stoppages were conducted in four mines. Each mine had requested that NIOSH researchers conduct a survey to evaluate the effects of a main mine fan stoppage on methane levels along haulageways. Entries to each of the four mines consisted of a slope, two drift portals and one shaft.

NIOSH researchers visited each mine prior to the day of the fan stoppage. Researchers traveled underground, inspected each sampling area and decided on the best methanometer sampling location. On the morning of the survey, approximately one hour before the mine fan was shut down, researchers and mine personnel positioned and started methanometers at each location. Once all instruments were in position and operating, everyone evacuated the mine and the fan was shut down. Total time the fans were turned off varied from about three to five hours. After the fan was restarted and the mine re-inspected, the instruments were brought to the surface by mine personnel. The methane concentration data was retrieved from each data logger using software provided by the manufacturers. Spreadsheets were created to chronicle the data. Graphs were then derived to enable researchers to view the results.

3.2 *Surface*

To determine methane concentrations being exhausted from the mine before the fan was stopped and again following fan restart, air samples were taken just downstream of the main mine fan evasé. Evacuated test tubes were used to collect and preserve the air samples. One sample was taken before the fan was shutdown. Following the fan restart, samples were obtained every five minutes for one hour. As previously described, the sampling tubes were then returned to the laboratory for analysis. GC results provided the concentrations for all major atmospheric gases including carbon monoxide, and hydrocarbons from methane to pentane.

4 RESULTS

In each of the four mines evaluated, methane concentrations were monitored continuously at five to ten locations along the haulageways. Methane measurements were also made in areas near one or two of the active working faces. In three of the mines, methane concentrations along the haulageways remained at or below the detection limit of the methanometer for the entire time the fan was shut down. At the fourth mine, with the exception of two locations, all other readings along the haulageways remained zero.

Mine No. 2 results are included in this report as an example of the data that researchers obtained from these evaluations. The fan was turned off at Mine No. 2 for approximately three hours. A schematic of the areas sampled at Mine No. 2 is shown in Figure 1. The initial and final methane concentrations at the locations along the haulageways and on the sections are given in Table 1. The methane increase to 0.2 pct at Location 1 was not readily explainable. The increase to 0.7-pct methane at Location 7 was most likely due to the location's proximity to a bleeder evaluation point.

Table 1. Mine No. 2 methane concentrations.

Haulageway Methane Concentrations, (%) CH_4			Section Methane Concentrations, (%) CH_4		
Location	Fan Stop	Fan Restart	Location	Fan Stop	Fan Restart
1.	0.1	0.2	8.	0.0	0.4
2.	0.0	0.0	9.	0.1	1.0
3.	0.0	0.0	10.	0.1	1.3
4.	0.0	0.0	11.	0.1	1.3
5.	0.0	0.0	12.	0.0	0.4
6.	0.0	0.0			
7.	0.0	0.7			

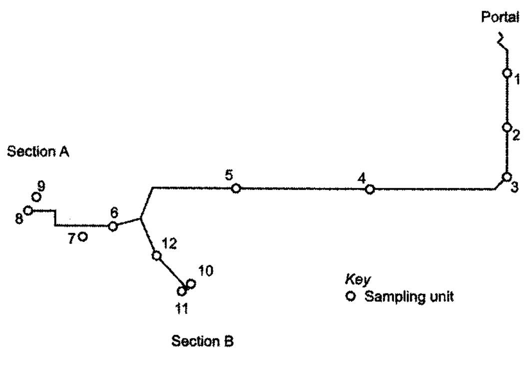

Figure 1. Areas sampled at Mine 2.

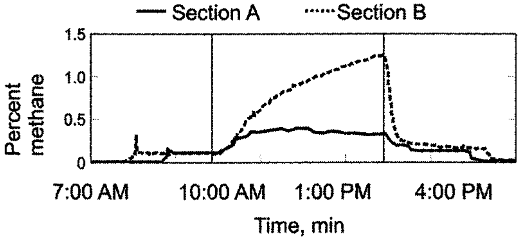

Figure 2. Face concentrations at Mine 2.

Methane concentrations increased at the working faces in Mine No. 2 (locations 8 and 10) when the fan was shut down. The increases varied from 0.4 to 1.2 pct. After the mine fan was restarted, concentrations decreased quickly to levels measured prior to the fan stoppage. Figure 2 shows the variation in methane concentrations measured near the two faces (Sections A and B) in Mine No 2.

The results of bottle samples collected in the main fan exhaust at each of the four mines during the first hour following fan restart are shown in Figure 3. Methane levels varied between mines but the concentrations at each fan increased gradually at all mines following the fan restart. Within an hour the fan methane concentrations at all four mines had decreased to levels close to those measured before the fan was stopped.

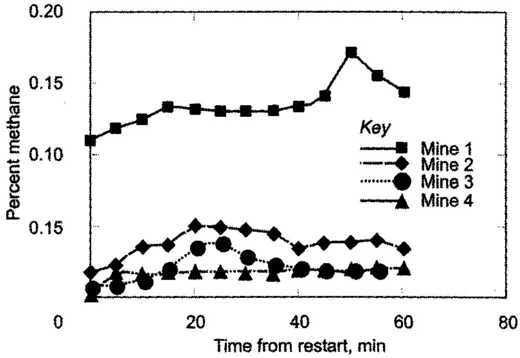

Figure 3. Methane concentrations in fan exhaust after restart.

5 DISCUSSION AND CONCLUSIONS

Studies were conducted in four underground mines to evaluate methane levels along haulageways during planned stoppages of the main mine fans. In three of the four mines there were no increases in methane levels along the haulageways while the fan was off. Liberation rates were very low in each of the four mines.

The highest methane concentrations measured during the fan stoppage studies were in Mine No. 2. In Mine No. 2, methane increased by 0.1 pct in one area (Location 1) and 0.7 pct in another (Location 7). Again, these values were well below the LEL for methane. Locations 1 to 7 were on track haulage routes that would be used by miners traveling from sections A and B to the mine portal. Location 7 was a bleeder evaluation point located close to the track. The remaining sampling locations (8 to 12) were in the active working sections designated A and B. At locations 8 and 10 the methanometers were located within 10 ft of the face. At locations 9 and 11 the methanometers were in the immediate return entries within 100 ft of the face, and location 12 was in the main section return within 300 ft of the face.

The information obtained during the study at Mine No. 2 was evaluated to determine the relative risk associated with using powered haulage to remove workers from the mine during a fan shutdown. As seen in Figure 1, methane concentrations on the sections began to increase at the active mining face almost as soon as the fan was turned off. If the miners would have left sections A and B 15 minutes after the fan was shut down, the highest methane concentrations measured at the two faces would have been 0.2 and 0.4 pct respectively. Assuming the miners would reach the portal by powered haulage less than 1 hour after the fan stops, the highest methane concentration encountered along the haulageway would have been 0.2 pct at location 1, as shown in Table 1. Since, the potential for a frictional ignition is related to the methane concentration, the risk to safe egress via powered vehicles is obviously very low. In fact, at Mine 2 the risk to miners due to the exposure to methane during powered haulage evacuation should be no greater than for miners working at the mining face.

Although methane concentrations increased slightly at some locations during the fan shut down, the levels remained well below the LEL. If the duration of the fan stoppages was longer, the methane concentrations may have continued to increase. However, at all the mines surveyed there would have been sufficient time (3 to 5 hours) for the workers to evacuate the mine before methane concentrations along the haulageways exceeded 0.2 pct.

Methane concentrations measured in all four main fan exhausts increased after the fan was restarted. This was due to methane that had accumulated throughout the mine during the fan stoppage. The amount of gas accumulated during the stoppage depends on the liberation rate in the mine and the time the fan was off. For mines 1, 2, 3 and 4, the actual times the fans were off were 5, 4, 3, and 5 hours. Since concentrations in areas sampled along the haulageways did not increase significantly during the time the fan was off, gas levels must have increased in other mine areas. Most likely methane levels rose in face areas, at bleeder evaluation points and in return entries. In Mine No. 2, after the fan was restarted, the methane concentrations measured on sections A and B indicated the movement of methane was away from the faces and toward the fan. Data from the two locations sampled on section A and the three locations sampled on section B are included in Figure 4. As noted in Figure 1, the methane levels began to decrease at the face almost as soon as the fan was restarted. Twenty to thirty minutes later there was an increase in methane concentration at the immediate return locations, about 100 ft outby the face. Concentrations in the main return of section B, 300 ft outby the face, increased about 90 minutes after the fan was restarted.

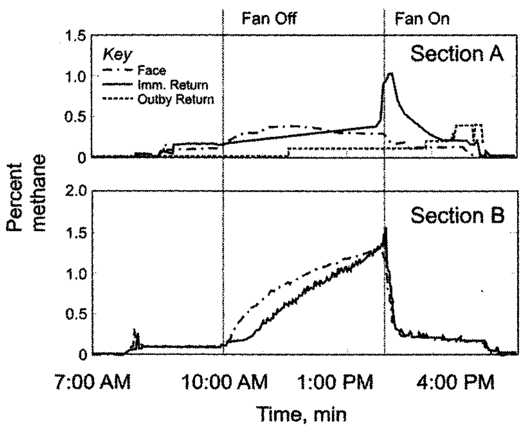

Figure 4. Methane concentrations measured on sections A and B.

Although there were no significant accumulations of methane along the haulageways during the fan shut down, methane did accumulate near the work faces and at sampling Location 7, positioned adjacent to a haulageway. The effect of these accumulations on worker safety during the time of mine evacuation appeared to be minimal.

Many different factors can cause methane levels in mines to vary. The information obtained during these underground studies only applies to the mines where the studies were conducted. Any changes in operating conditions that might affect mine ventilation (such as localized atmospheric phenomena) could periodically affect methane levels at any one mine. The effects of ventilation changes on methane levels in particular mines can be determined only by additional site-specific research.

Methane concentrations must be measured during a fan stoppage to evaluate the potential risk to workers exiting the mine via powered haulage while the fan is not operating. Methanometers with the capability of recording data must be used since the instruments must be placed in the mine before and after the fan stoppage. Ventilation conditions are continuously changing in a mine and the measurements taken are valid estimates of methane concentration only for the conditions existing at the time of the study.

For these tests selection of sampling areas was based primarily on the experience of mine personnel. When developing a test plan for monitoring methane concentrations along haulageways it is recommended that government enforcement and local mine safety personnel be consulted.